Flexible integrated photonics: shedding light into the flexible electronics toolkit

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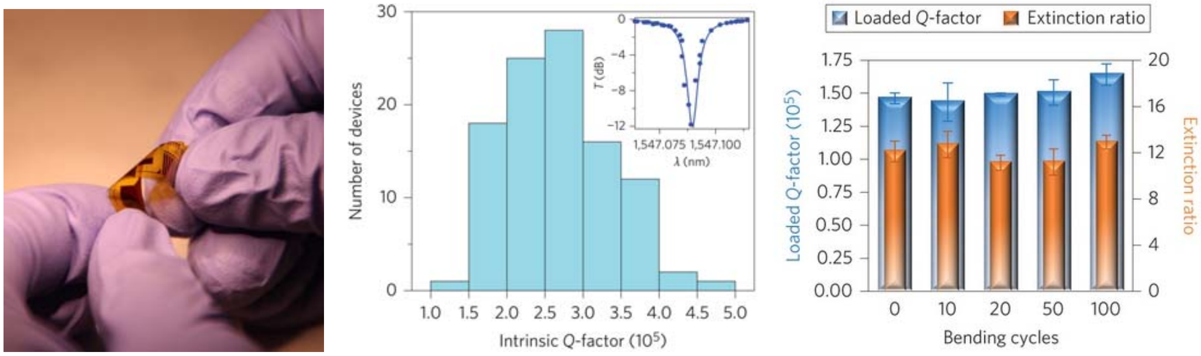
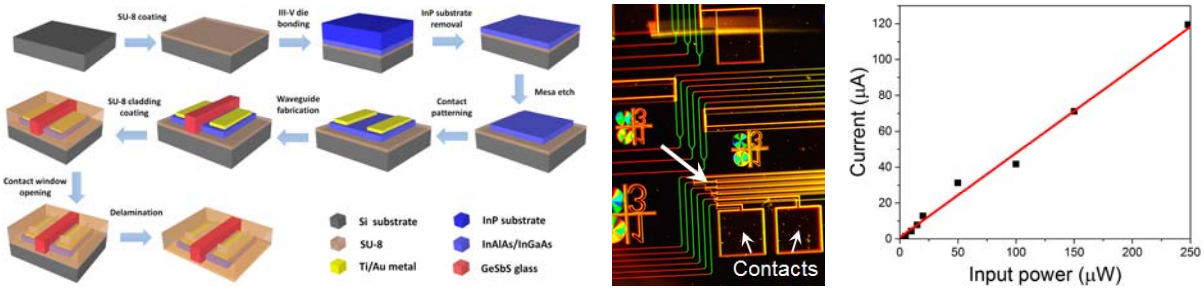
While flexible electronics has been a well-established field with several decades of research and development under the belt, flexible integrated photonics is a nascent technology that has only started to burgeon in the past few years. Compared to conventional free-space optical and optoelectronic components, integrated photonic devices offer a number of performance benefits including small footprint, high bandwidth, superior ruggedness (immunity to misalignment), reduced cost, as well as enhanced signal-to-noise ratio enabled by strong optical confinement and minimal sensitivity to stray ambient light. Therefore, integrated photonics is poised to make a significant impact on optoelectronic system integration on flexible substrates.



(a) (b) (c)

Fig. 1. (a) Photo of a flexible photonic chip. (b) Intrinsic Q-factor distribution measured in flexible optical resonators. Inset: example of resonator transmission spectrum. (c) Loaded Q-factors and extinction ratios of the resonator after multiple bending cycles at a bending radius of 0.5 mm.

This talk will review the progress made by our research team in material development, micro-mechanical design and device engineering towards enabling novel flexible integrated photonic systems. Our integration process synergistically combines monolithic glass (TiO_2 or chalcogenides) deposition with hybrid semiconductor nanomembrane bonding to enable full active-passive system integration. Fig. 1 shows a passive flexible photonic circuit which exhibits record low optical loss. Extraordinary mechanical flexibility results from a novel multi-neutral-axis configurational design: the devices can sustain repeated folding down to sub-millimeter bending radius without measurable performance degradation [1-3]. The multi-material integration process was also implemented to demonstrate flexible waveguide-integrated photodetector arrays (Fig. 2) with a measured responsivity of 0.5 A/W at 1550 nm telecommunication wave band and an average quantum efficiency of 40% [4]. We further investigated biocompatibility of the flexible photonic devices through cytotoxicity studies [5]. No statistically significant difference was observed for hMSC proliferation for cells in direct contact with the optical materials and with tissue culture plate reference, which confirms cytocompatibility of the flexible photonic devices (Fig. 3). These results pave the path towards emerging applications of the flexible photonics technology such as epidermal sensing, optical imaging, optogenetic modulation, and data communications.



(a) (b) (c)

Fig. 2. (a) Fabrication process of the flexible waveguide-integrated photodetector. (b) Optical microscope image of the fabricated detectors. The thick arrow indicates location of the detector pixels. (c) Photo response of the detector.

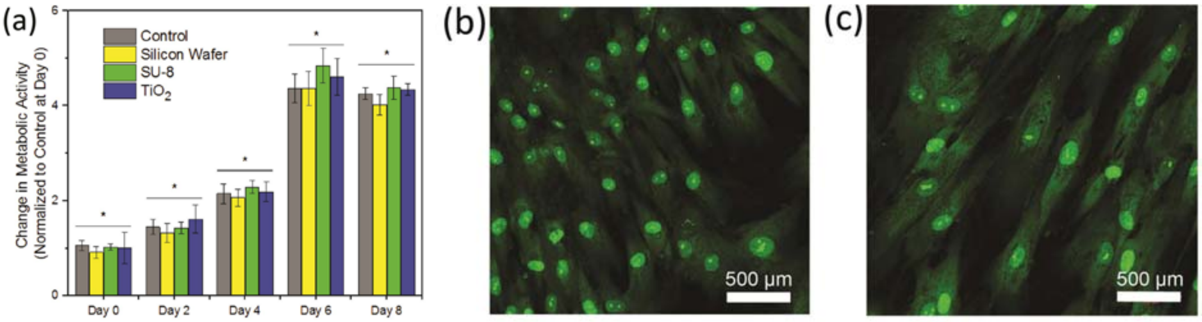


Fig. 3. (a) Proliferation of hMSCs in indirect contact with optical materials; (b, c) confocal images of live/dead stained day 10 hMSCs cultured in direct contact with SU-8 (b); and TiO_2 (c). Live cells were stained green and dead cells, if any, were stained red.

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